(8) 1. Figure 1 shows the location of two positively charged particles, Q_1 and Q_2. The particle denoted Q_1 has a positive charge of 0.5 nC and the particle denoted Q_2 has a positive charge of 2.0 nC. The two particles have (x,y) coordinates (2,2) and (10,10) respectively, where each coordinate has units centimeters.

✓ (a) Find the total force on a test charge, say Q_t, of $+2 \times 10^{-2}$ C when it is at point A (point A has coordinates (6,2)).

✓ (b) How much work is required to move the test charge from point A to point B (point B has coordinates (6,10))?

✓ (c) What is the electric potential of +1 C of charge at point B w.r.t. point A (i.e. what is V_{BA})?

✓ (d) Show the electic field vector in Figure 1 at point D (point D has coordinates (8,8)). Clearly indicate direction with an arrow (vector) and mark the electric strength (magnitude) along its side.

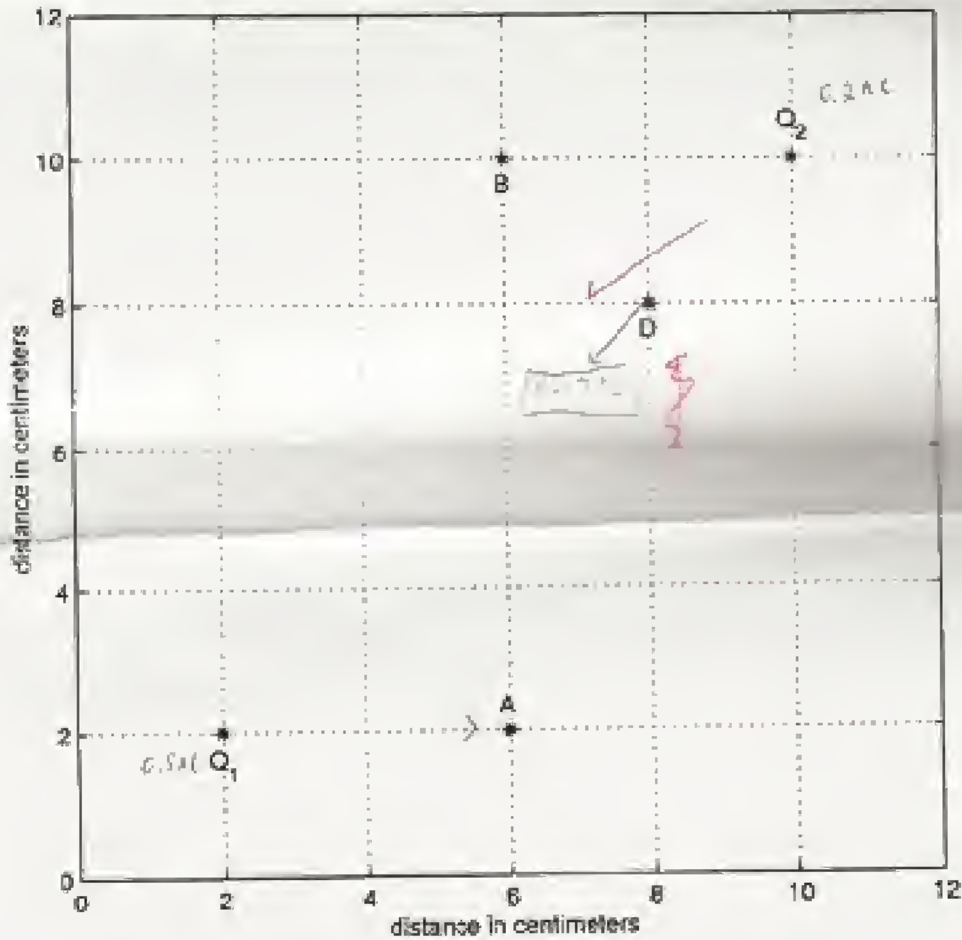

Figure 1: Charge is located at points Q1 and Q2

A) $F = \frac{k|Q_1||Q_2|}{r^2}$

$F = \frac{(9.0 \times 10^9 \frac{Nm^2}{C^2})(0.5 \times 10^{-9} C)(2 \times 10^{-2} C)}{(\ldots)^2}$

(9) 2. Figure 2 shows equipotential contours in an electric field. The map is not drawn to scale but has distance marked on the x and y axes. The contour lines represent 1 volt steps. The voltage of point B w.r.t. point A is 7 volts. $V_{BA} = 7V$

(a) Draw the electric field line that passes through point D. Be sure to mark the direction.

(b) What is the electric potential of +1 C of charge at point B w.r.t. point D?

(c) Approximately what is the magnitude of the electric force on a particle with +7 mC of charge if that particle is placed at point F.

(d) Some test charge, Q_t, of unknown amount and sign is placed at A. This charge experiences a total electric force of 10 N. It is known that the y component of the electric force is positive (i.e. upward).

   i. What is the sign of the test charge?

   ii. Approximately, what is the magnitude of Q_t?

   iii. Approximately, what is the x component of the electric force (i.e. force in horizontal direction)?

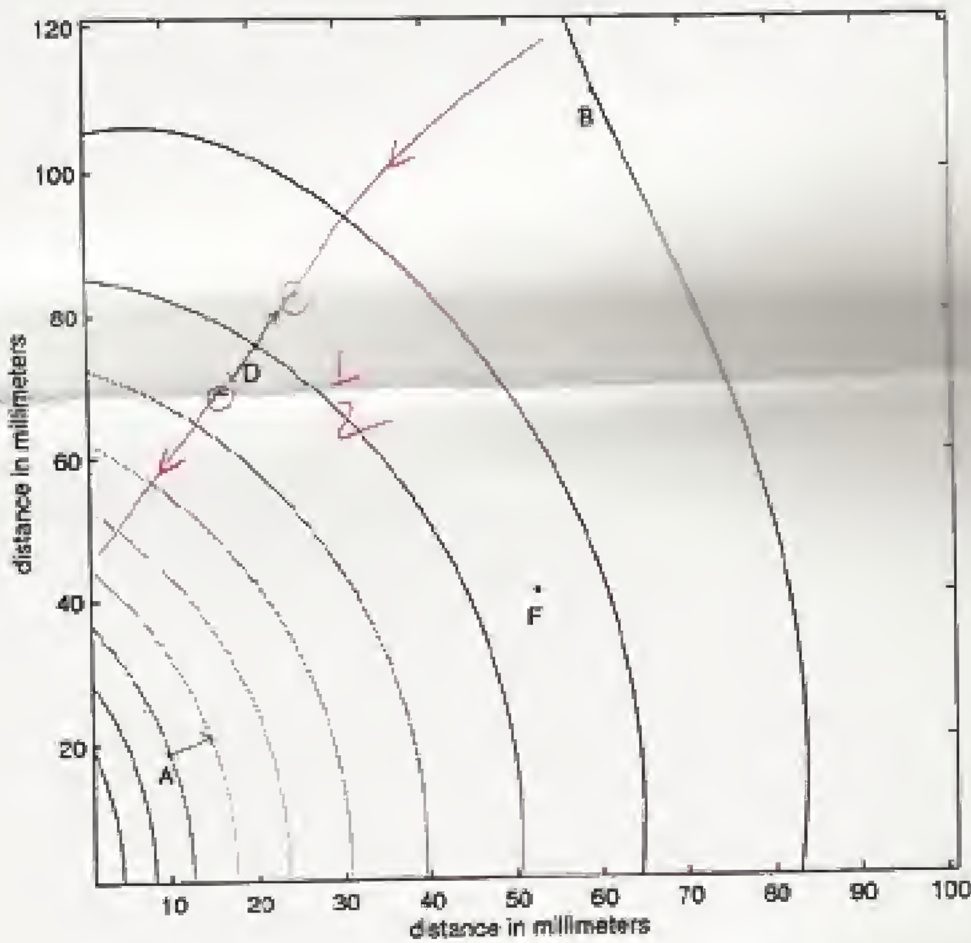

Figure 2:

A) see diagram

B) V_{BD} = (+1)([illegible]) = [illegible]

D) i) positive

D) [illegible]

(6)

3. An aluminum wire 1500 m long has a resistance of 7 ohms. A copper wire has the same cross section area as the aluminum wire but is 1000 m long. The two wires are connected in series. Both wires are at a temperature of 20 degrees centigrade.

   (a) What is the resistance of the two wires in series?

   (b) What is the resistance of just the aluminum wire, if the temperature of the aluminum wire is changed to −50°C?

   (c) What is the temperature coefficient at 20°C of the dual composition resistor which is the aluminum and copper wires connected in series?

A):

$R_1 = 7\,\Omega$

$R_1 = \frac{\rho L}{A}$

$A = \frac{\rho L}{R_1}$

$A = \frac{(2.825 \times 10^{-8})(1500)}{(7)}$

$A = 6.05 \times 10^{-6}\ m^2$

$R_2 = \frac{\rho L}{A}$

$R_2 = \frac{(1.724 \times 10^{-8})(1000\,m)}{(6.05 \times 10^{-6}\,m^2)}$

$R_2 = 2.85\,\Omega$

2

$R_T = R_1 + R_2$

$R_T = (7\,\Omega) + (2.85\,\Omega)$

$R_T = \boxed{9.85\,\Omega}$

B) $R_2 = R_1 \left(\frac{T_2 - T_I}{T_1 - T_I}\right)$

2

$R_2 = (7)\left(\frac{-50 + 236}{20 + 236}\right)$

$R_2 = (7)(0.727)$

$R_2 = \boxed{5.09\,\Omega}$

c) $\alpha_1 = \frac{1}{T_1 - T_I}$

$\alpha_1 = \frac{1}{20 + 236}$

$\alpha_1 = 3.91 \times 10^{-3}\ {}^\circ C^{-1}$

$\alpha_2 = \frac{1}{T_2 - T_I}$

$\alpha_2 = \frac{1}{20 + 234.5}$

$\alpha_2 = 3.93 \times 10^{-3}$ [illegible]

$\alpha_{total} = \frac{\alpha_1 + \alpha_2}{2}$

$\alpha_{total} = \frac{(3.91 \times 10^{-3}) + (3.93 \times 10^{-3})}{2}$

$\alpha_{total} = \boxed{3.92 \times 10^{-3}\ {}^\circ C^{-1}}$

(6) 4. A resistor has a temperature coefficient of $0.007°C^{-1}$ at 20°C. It has a resistance of 100 Ω at 50°C. What is its resistance at 0°C?

$R_2 = R_1 [1 + \alpha_1 (T_2 - T_1)]$

$100\,\Omega = R_1 [1 + (0.007)(50-20)]$

$100 = R [1 + 0.21]$

$100 = R_1 (1.21)$

$R_1 = 82.6\,\Omega$

$\cancel{R_2 = R_1 [1 + \alpha_1 (T_2 - T_1)]}$

$\cancel{R_2 = (82.6)[1 + (0.007)(0-20}$

$\alpha_{20} = \dfrac{1}{T_{20} - T_I}$

6

$0.007 = \dfrac{1}{20 - T_I}$

$0.007(20 - T_I) = 1$

$-0.007\,T_I = 1 - 0.14$

$0.007\,T_I = $ [illegible]

$T_I = -122.9\ °C$

$R_2 = R_1 \left(\dfrac{T_2 - T_I}{T_1 - T_I}\right)$

$R_2 = (82.6)\left(\dfrac{0 + 122.9}{20 + 122.9}\right)$

$R_2 = 82.6$ ([illegible])

$R_2 = \boxed{\text{[illegible]}}$

5. A series circuit is shown in Figure 3. The current flowing in the circuit is 10 mA clockwise. The values of resistor R_1 and battery E are unknown.

   (a) What is V_{AB}? The sign of your answer must be correct to get full credit for this question.

   (b) At what rate is energy converted from chemical energy to electrical energy by the 20 V battery. The sign of your answer must be correct to get full credit for this question.

   (c) If R_1 converts electrical energy to heat at the same rate as the 20 volt battery, what is the value of E?

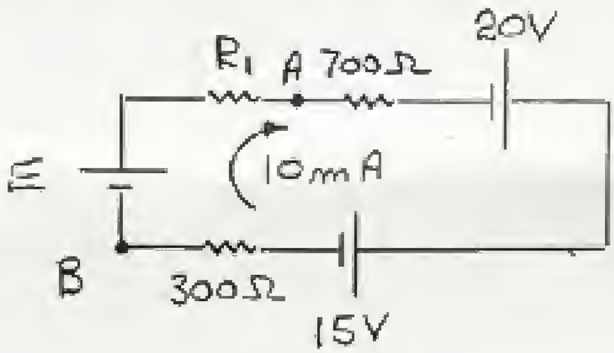

Figure 3

$\Sigma V = 0$

[illegible]

0

X

A) $V_{AB} = (300\Omega)(0.01A) - 15V + 20V + (700\Omega)(0.01A)$

$V_{AB} = 3V - 15V + 20V + 7V$

$V_{AB} = \boxed{15V}$

4)

6\. (a) A series circuit is shown in Figure 4. The power dissipated by resistor R_2 is twice that of R_1 and the power dissipated by resistor R_3 is three times that of R_1. What is the voltage across R_2, i.e. V_{AB}.

✓ (b) What is the voltage of battery E in the circuit shown in Figure 5 if the current is 300 mA in the clockwise direction? The sign of your answer must be correct to get full credit for this question.

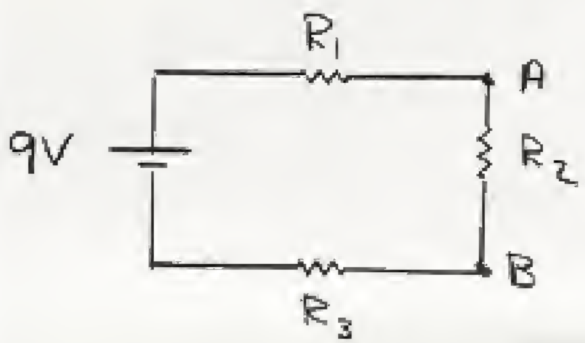

Figure 4

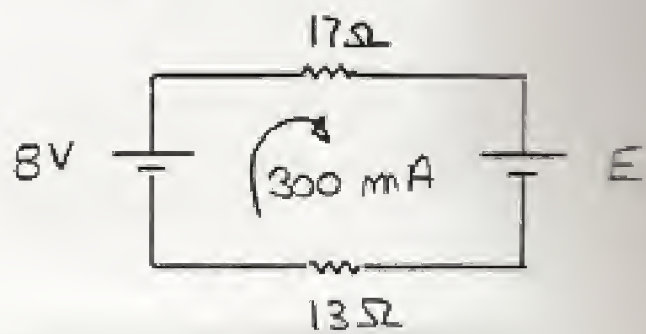

Figure 5

A) $R_2 = 2R_1$ $\qquad R_1 = \frac{1}{2}R_2$

$R_3 = 3R_1$ $\qquad R_3 = 3(\frac{1}{2}R_2) = \frac{3}{2}R_2$

$\Sigma V = 0$

$0 = 9V - I(R_1 + R_2 + R_3)$

$0 = 9V - I(\frac{1}{2}R_2 + R_2 + \frac{3}{2}R_2)$

$9V = I(3R_2)$

$3V = R_2 I$

$R_2 = \frac{3V}{I}$

$R_2 = \boxed{3V}$ √2

B) $\Sigma V = 0$

$0 = 8V - E - (17\Omega)(0.3A) - (13\Omega)(0.3A)$

$E = 8V - 5.1V - 3.9V$

$E = \boxed{-1V}$ √2

7. A series circuit is shown in Figure 6. The current is 20 mA in the counter-clockwise direction. What is $V_A - V_B$?

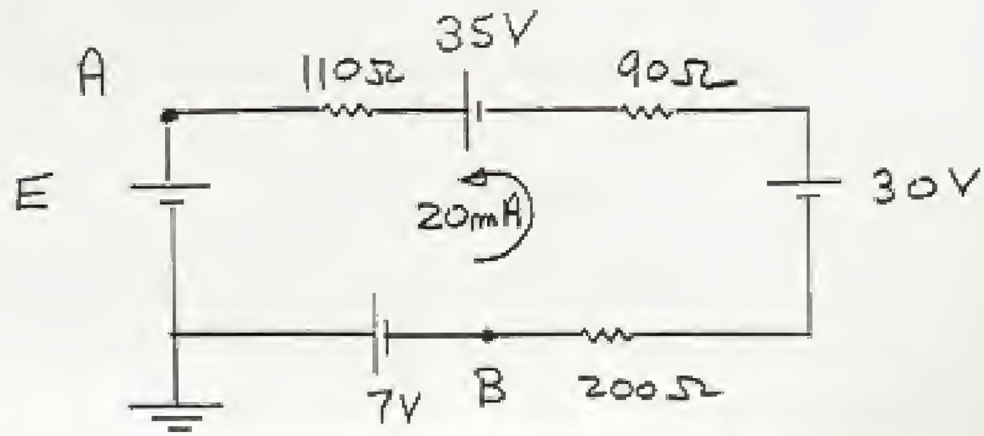

Figure 6

$\Sigma V = 0$

$0 = -E + 35V + 30V - 7V - (110\,\Omega)(0.02A) - (90\,\Omega)(0.02A) - (200\,\Omega)(0.02A)$

$E = 58V - 2.2V - 1.8V - 4V$

$E = 50V$

$V_A = 50V$ $\qquad$ $V_{AB} = V_A - V_B$

$V_{AB} = 50V - (-7V)$

$V_B = -7V$ $\qquad$ $V_{AB} = \boxed{57V}$ ✓ 4